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(54) Title of the Invention LIGHT AMPLIFYING ELEMENT

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Description

1. Title of the Invention

LIGHT AMPLIFYING ELEMENT

2. Patent Claim

A light amplifying element characterized in that a cylindrical clad body is provided around a columnar core body with a high refractive index that serves for guiding a pumping light, the clad body has a refractive index lower that that of the core body, and a plurality of rod-like light-emitting bodies are arranged inside the clad body.

3. Detailed Description of the Invention

[Field of Industrial Use]

The present invention relates to a light amplifying element, and more particularly to a small, fiber-type light amplifying element enabling the integration.

[Prior Art Technology and Problems Relating Thereto]

Semiconductor lasers, which are injection-type lasers, and laser generation devices based on external pumping such as glass lasers and gas lasers have heretofore been used for light amplification.

However, glass lasers and gas lasers are difficult to miniaturize. Yet another drawback thereof is that such devices are difficult to integrate to amplify a large number of lights at the same time. The drawback of semiconductor lasers is that the output is low and coupling with optical fibers is difficult.

[Means to Resolve the Problems]

In accordance with the present invention, by providing a clad body around a core body that guides the external pumping light and arranging a plurality of light-emitting bodies in the clad body, the size can be reduced, integration is enabled, output is high, and coupling with optical fibers can be easily performed.

Fig. 1 shows an example of the light amplifying element in accordance with the present invention. The reference number 1 in the figure stands for a core body. The core body 1 serves to guide the pumping light from an external light source. Here, the core body is a round columnar body with a diameter of 100-200 μm and a length of about 0.5-10 mm. The core body 1 is produced from a multi-component glass or quartz glass with a refractive index higher than that of a surrounding clad body 2. The cylindrical clad body 2 is provided around the core body 1 integrally therewith.

The clad body 2 has a refractive index lower than that of the core body 1 and is produced from an oxide crystalline material such as ruby, YAG, and alexandrite, or from a multi-component glass containing oxides, e.g., of alkali metals, alkaline earth metals, aluminum, and boron. The length of the clad body is equal to that of the core body 1.

A plurality (here, 4) small-diameter round-rod-like light-emitting bodies 3... are embedded in positions arranged equidistantly on a circle in the clad body 2, the central axes of the light-emitting bodies being parallel to the axial direction of the core body 1. The diameter of the light-emitting bodies 3... is about 2-10 μm, and this diameter is selected to match the core diameter of single-mode optical fibers that are connected thereto and serve to guide the incoming and outgoing light. The length of the light-emitting bodies is equal to that of the core body 1 and clad body 2. The light-emitting bodies 3 are made from a laser substance enabling inverted distribution, such as crystalline material, e.g., Cr-ruby, Nd-YAG, Nd-YIG, Nd-$LiNbO_3$, Nd-$LiTaO_3$, or Nd-multi-component glass. The refractive index of the light-emitting bodies is higher than that of the clad material 2.

Further, a high-reflective film 4 composed, e.g., of a gold vapor-deposited film with a reflection factor of 98-99% is formed on one end surface of the round rod-like assembly composed of the core body 1, clad body 2, and light-emitting bodies 3..., and a low-reflective film 5 composed, e.g., of a gold vapor-deposited film with a lower reflection factor (about 95%) is formed on the other end surface. Those two reflective films 4, 5 are parallel to each other. The reflective films are not provided on the end surface of the core body 1 on the side of pumping light input.

A method for using such light amplifying element will be described below with reference to Fig. 2.

First, an optical fiber 6 for pumping that serves to guide the pumping light is connected to the end surface of the core body 1 on the side where no reflective film is provided. A large-diameter quartz optical fiber with a core diameter of 100-200 μm is mainly used as the optical fiber 6 for pumping in order to guide the high-power light. The core of the optical fiber 6 for pumping can be inserted without a gap into a hollow section in which the core body 1 of the light amplifying element is not provided, and in this case the core of the end section of the optical fiber 6 for pumping also serves as the core body 1 of the light amplifying element.

Further, one end of single-mode optical fibers 7... for input that serve to introduce the input light is connected to the end surface of light-emitting bodies 3... where the high-reflective film 4 is provided. The other end of each single-mode optical fiber 7... for input is connected to the respective input light source. As shown in Fig. 2, the entire light amplification system can be miniaturized if the connection is made to the output ends of semiconductor lasers of an integrated semiconductor laser 8 in which four semiconductor lasers are integrated.

Single-mode optical fibers 9... for output that lead the amplified light out are connected to the end surface of the light-emitting bodies 3... where the low-reflective film 5 is provided.

The pumping light from a light source 10 such as a xenon lamp, a halogen lamp, and a high-power laser is introduced all the time into the optical fiber 6 for pumping, the light-emitting bodies 3... are energized, and a reversed distribution state is assumed. In this state, if the input

pulse light is inputted from the integrated semiconductor layer 8 into the light-emitting bodies 3… via optical fibers 7… for input, the light-emitting bodies 3… are laser induced, and the output light is outputted from the low-reflective film 5 into the optical fibers 9… for output.

A method for manufacturing the light amplifying element will be described below.

First, when the clad body 2 and light-emitting bodies 3 are crystalline materials, the hollow clad body 2 having no core body 1 or light-emitting bodies 3… is produced by an EFG method (edge defined film fed gross method) using a pulling die. Then, crystals are grown, e.g., by a Bridgman method in the cavities of the clad body 2 where the light emitting bodies 3… are to be accommodated, and the light-emitting bodies 3… are formed. Then, the clad body 2 having the light-emitting bodies 3… provided therein is cut to the predetermined length, both end surfaces are optically polished, and a metal such as gold is deposited to form the reflective films 4, 5. Then, the cores of the end sections of the large-diameter optical fibers 6 for pumping are inserted, as described above, into the cavities where the core body 1 is accommodated and the light amplifying element is obtained.

In the case where the clad body 2 and light-emitting bodies 3 are from multi-component glass, a large-diameter round rod-like glass reform is prepared, and holes for accommodating the core body 1 and light-emitting bodies 3… are provided therein. Then, the rod-shaped glass preforms that will serve as light-emitting bodies 3 are inserted into the holes where the light-emitting bodies 3… are to be accommodated, followed by rolling under heating. As a result a rod of the predetermined diameter is obtained. The rod is cut to the predetermined length, the end surfaces thereof are optically polished, reflective films are then provided, and finally, the core of the optical fiber for pumping is inserted into the cavity where the core body 1 has to be accommodated, thereby providing a light amplifying element.

In such light amplifying element, by disposing a plurality of light-emitting bodies 3… in the clad body 2, lights with a plurality of different wavelengths can be amplified at the same time, the so-called integration is possible, and the shape can be miniaturized. Furthermore, the joining surface in connecting the input and output optical fibers 7…, 8… is large and flat.

Therefore, the connection is facilitated and the coupling efficiency is good. Moreover, if the input of pumping light is increased, a high input can be easily obtained.

[Embodiments]

[Embodiment 1]

A sapphire fiber that will serve as a clad body of a cross-sectional shape shown in Fig. 3 was grown by the EFG method by using a molybdenum die. Nd-YAG single crystals were grown by a horizontal Bridgman method in the holes where the light-emitting bodies are to be accommodated. The fibers were then cut to a length of 10 mm, the end surfaces thereof were polished to be parallel, a low-reflective film with a reflection factor of 95% was formed by vapor deposition of gold (Au) on one end surface, and a high-reflective film with a reflection factor of 98% was vapor formed from gold on the other end surface. A core of a step-index-type optical fiber for pumping with a fiber diameter of 250 μm, a core diameter of 200 μm, and $\Delta = 1.5\%$ was exposed and inserted into the cavity section where the core body of the central section is to be accommodated, thereby producing a light amplifying element.

A total of six single-mode optical fibers with a core diameter of 6 μm and fiber diameter of 125 μm were connected to both end surfaces of the light-emitting bodies of the light-amplifying element. The input optical fibers were connected to the output ends of an integrated semiconductor layer having integrated therewith a total of six injection-type InGaAs lasers (wavelength 1.06 μm, output 30 mW), the optical fibers 6 for pumping were connected to a Ne-He gas laser (wavelength 0.633 μm), and the pumping light was inputted into the core body. The output of the Ne-He gas laser was then raised to several W, the light-emitting bodies were energized, and in this state a laser beam was inputted in a pulse fashion from the integrated semiconductor laser. As a result, a pulsed light with a wavelength of 1.06 μm and an output of 950 mW was outputted from the light emitting body.

[Embodiment 2]

A hole with a diameter of 20 mm was formed by polishing in the central section of a round rod-like preform composed of calcium aluminate glass with a diameter of 40 mm. A total of 8 holes with a diameter of 0.5 mm were formed by polishing in the circumferential section. A glass preform having an index-graded distribution with $\Delta = 0.5\%$ was accommodated in the hole with a diameter of 20 mm, and glass performs from Nd-calcium aluminate glass with $\Delta = 0.3\%$ were accommodated in the holes with a diameter of 0.5 mm. The resultant configuration was rolled and a fiber with a cross-sectional structure shown in Fig. 4 was obtained. This fiber was then cut to a length of 30 mm, both end surfaces were optically polished, and reflective films were formed in the same manner as in Embodiment 1. Then, the input-output optical fibers were connected, those fibers being identical for both end surfaces of the light-emitting bodies.

The input optical fibers were connected to an integrated semiconductor layer (wavelength 0.86 μm, output 100 mW) comprising 8 lasers, large-diameter multi-component optical fiber with a fiber diameter of 250 μm and a core diameter of 200 μm was connected to the core body, the pumping light from a xenon lamp was introduced, and the light-emitting bodies were energized. When a pulsed light was inputted from the integrated semiconductor laser, a pulsed light with a wavelength of 0.86 μm and an output of 1.5 W was outputted.

[Effect of the Invention]

As described hereinabove, in the light amplifying element in accordance with the present invention, a cylindrical clad body is provided around a rod-shaped core body for guiding the pumping light, and a plurality of light-emitting bodies are disposed in the clad body. Therefore, a plurality of lights can be amplified at the same time, integration is possible, and the size can be reduced. Furthermore, connection of the input-output optical fibers is facilitated and the coupling efficiency is good. In addition, a high output can be obtained despite a small size.

Brief Description of the Drawings

Fig. 1 is a perspective view illustrating an example of the light amplifying element in accordance with the present invention. Fig. 2 is an explanatory drawing illustrating a method for using the light amplifying element in accordance with the present invention. Fig. 3 and Fig. 4 are front views illustrating the dimensions and shape of the light amplifying element obtained in Embodiments 1, 2.

1 ... core body, 2 ... clad body, 3 ... light-emitting body.

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Figure 1

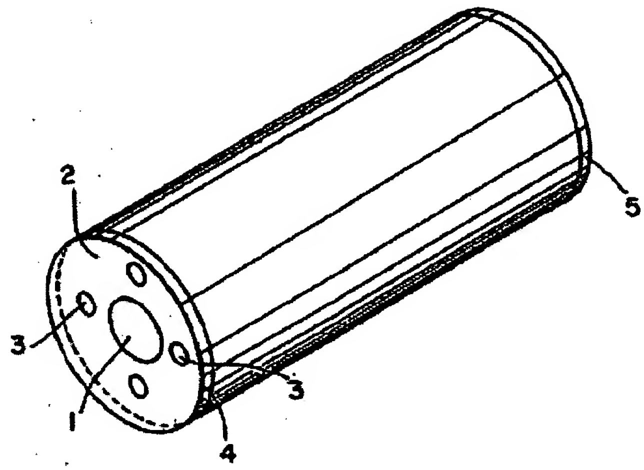

Figure 2

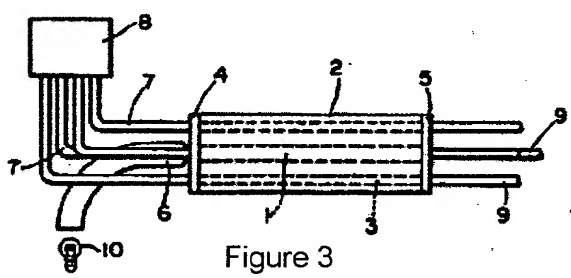

Figure 3

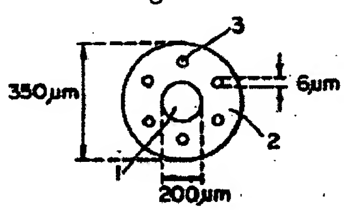

Figure 4